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A new compact grounded coplanar waveguide slotted multiband planar antenna for radio frequency identification data applications

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ABSTRACT

This research presents the development and conception of a new compact grounded coplanar waveguide fed slotted rectangular planar antenna with a multi-frequency band for radio frequency identification data (RFID) reader applications which is based on the antenna mono-band frequency to use for a various applications RFID to support a different operating range. The optimized of the final prototype designing operates a multiple frequency bands ranging from 0.7-1.1 GHz, 2.2-2.5 GHz and 5.4-6 GHz for 0.9/2.4 GHz and 5.8 GHz RFID operation bands which is adapted from ultra-high frequency band (0.9 GHz) to microwave frequency band (2.4-5.8 GHz) RFID systems. This antenna is implemented and printed on a FR4 substrate with a size of 30×50×1.6 mm^3. The novel prototype includes of a radiator rectangular patch with a symmetrical slot and a U-slot with I-stub on ground plan. The principles parameters of the antenna have been studied optimized and miniaturized by using a two simulators CST Microwave Studio and advanced design system (ADS) to validate the simulation results before the planar antenna realization. The final structure is achieved and validated of the results measurement. Experimental results show that the proposed antenna with a small size has good and stable radiation and thus promising for a various RFID applications.

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1. INTRODUCTION

In recent years, a rapid evolution in wireless applications increase the development a new prototype compact planar reader antenna design with optimization dimensions to support a wireless radio technology such as radio frequency identification data (RFID) reader applications [1]–[3]. This is because the frequency bands super high frequency (SHF) and ultra-high frequency (UHF) can supply broad readable ranges and important data transfer rate [4]–[6]. Despite of the reality that this application very important in the world and diverse community have a different administrative standard for RFID frameworks. RFID is a recent engineering science in the wireless which use radio waves to send and receive data for the identification of object and has been used in the many applications, such as wirelessly readable tags for animals and moving vehicle identification [7] and cover a different frequency bands such as 130 KHz, 900 MHz, 2.4 GHz and 5.8 GHz for RFID applications [8], [9].

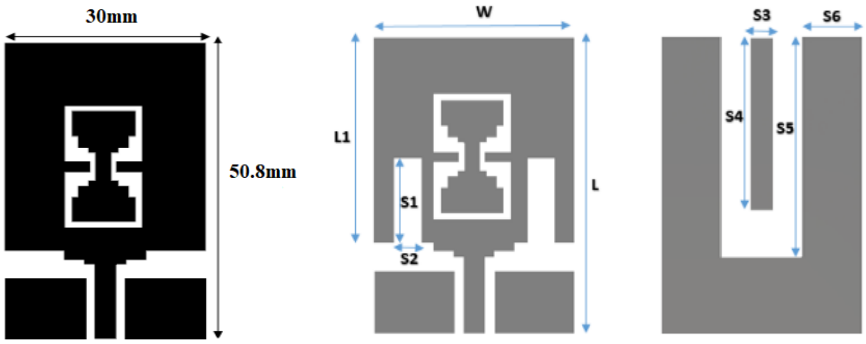
Recently, various antenna geometries with a single or multi-frequency band were announced for a various RFID application [10]–[12]. Planar antenna with a closely-space is proposed in [13] operate at 0.9 GHz and 2.4 GHz for RFID applications [14]. A dual frequency-band is developed and achieved for UHF and SHF RFID applications [15]. Another prototype planar antenna with multi frequency bands is proposed in [16]–[20], which can cover 0.9 GHz, 2.4 GHz and 5.8 GHz frequency bands. Multi frequency-band monopole printed antennas can be achieved by using a stub tuning, slot techniques and a parasitic structure with a different shape [21], [22].

This study we propose a new compact coplanar waveguide coplanar waveguide (GCPW) multi-band planar antenna for RFID applications. This planar antenna is based on different parameters; slot techniques and a stub tuning with optimum dimensions. Details of the final proposed antenna structure and the simulation and measurement results are discussed and discussed. The remainder of this work is organized: section2 explains the step-by-step design procedure, parametric study, and performance of the proposed antenna structure. In section 3, achievement and measurement results of the proposed structure antenna are discussed. Finally, conclusion is given in section 4.

2. ANTENNA PARAMETRES AND PERFORMANCES

The design evolution and a geometry of the final proposed antenna grounded coplanar waveguide line slotted is presented in the Figure 1(a) and Figure 1(b). This microstrip antenna prototype is printed on a FR4 epoxy substrate with a following characteristics: Dielectric permittivity: εr=4.4, Substrate thickness: h=1.6 mm and dielectric loss: tan(δ)=0.025. The conception and development of a new compact antenna with a multi-frequency bands for a various resonances radio frequency identification applications, a different parameters is analysis and studied such as variation the dimension of the shaped slots and a stub tuning with a specific position on the ground plane and a slot technique on radiator patch. Which a simple coplanar waveguide microstrip antenna reference is used with a large frequency band as shown in Figure 1(a) [19]. To excite by GCPW line with 50 Ω as characteristic impedance and adapted for a three-frequency band RFID application.

The aim goal the present design of this research is to develop a novel compact printed antenna with a multi-frequency resonance RFID. This proposed antenna studied is compared with a classical geometry microstrip antenna. The prototype antenna reference is excited by coplanar waveguide coplanar and cover a large impedance bandwidth matching over 28.5% and is suitable for SHF band ranging from 2.1 GHz to 2.8 GHz [23]. After adding a ground plane with optimized rectangular slot, a stub tuning and using a symmetrical slot on a radiator patch. The final prototype optimized antenna is operated for a three frequency-bands RFID reader. The various optimized dimensions of the final proposed structure antenna are listed in the Table 1.



(a) (b)

Figure 1. Geometry of the planar antenna structure (a) prototype reference and (b) prototype proposed

Table 1. Optimized dimension of final proposed planar antenna (unit: mm)

Parameter	Value	Parameter	Value
L	30	S3	
W	50.8	S4	
L1	37.1	S5	
S1	14.7	S6	
S2	4		

Improvement the design and performance of the suggested antenna structure is presented in the Figure 2. This study is based on the antenna reference, series miniaturization, and optimization which is done by using a simulator CST Microwave Studio (CST-MWS) for 3D electromagnetic which is based on the Finite integration techniques [24] and for a comparison results we have conducted by using another study by using a software simulator advanced design system (ADS) which contains different techniques and calculation methods [25]. Development of a new monopole planar antenna for a multi-frequency bands inserted by associating a various parameters such as GCPW line with optimum dimensions and slot shaped on the ground plane with cutting notched, using a stub tuning and a symmetrical slots on the radiator patch to adapt a three frequency bands for RFID applications by using optimizer tool (parameter sweep and post processing) which is based on genetic algorithm genetic algorithm (GA) embedded in CST Microwave Studio [20].

Therefore, the different steps the development of the proposed microstrip planar antenna is shown in Figure 3. We noticed the proposed design antenna is developed by three steps; firstly, by using a reference planar antenna with rectangular radiator patch and adapted a wideband spectrum in the range of 2.2 to 2.8 GHz for SHF RFID applications as shown in Figure 4. The monopole planar antenna reference design was modified by using a various parameter to develop and propose a new compact and miniaturized antenna for a various RFID frequency resonance; 0.9 GHz, 2.4 GHz and 5.8 GHz.

Therefore, a first step, for a reference antenna prototype, the geometry was modified by adding a ground plane with optimized dimensions of the rectangular slot on the bottom of the antenna reference as exhibited in Figure 5(a-i), it transforms into grounded coplanar waveguide line antenna with a frequency band ranging from 5.5 to 5.6 GHz and a frequency-band reference is dissipated of the planar antenna reference as shown in Figure 4. Secondly, after adding a rectangular slot with optimized dimensions on the ground plane, the dual-band is obtained 0.65 to 0.9 GHz and 5.6 to 6 GHz as plotted in Figure 5(a-ii). In the third step, by using a stub tuning slot with optimal dimensions and a position at the level on the rectangular slot as illustrated in Figure 5(b-i), permits to obtain planar antenna with a three frequency-band 0.8 to 0.9 GHz, 3 to 3.25 GHz and 5.45 to 6 GHz Figure 5(b-ii). At the end, to adapt the frequency band 2.4 GHz we used a symmetrical slot with optimal dimensions as decribed in Figure 5(c-iii). Thus, the reflection coefficient of the final antenna design is covering respectively a frequency-bands 0.7 to 0.9 GHz, 2.34 to 2.45 GHz and 5.65 to 6 GHz with a S11<=10 dB as shown in Figure 5(c). The final obtained result comparison with a reference antenna is illustrated in Figure 5(d).

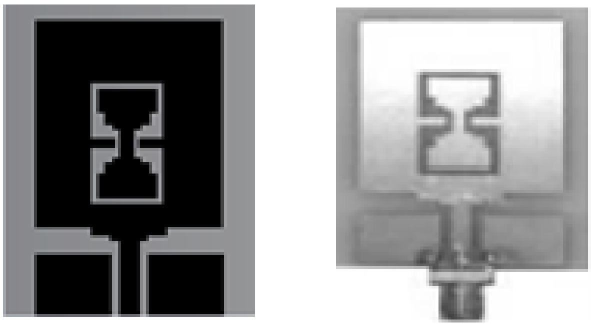


Figure 2. Structure antenna reference [23]

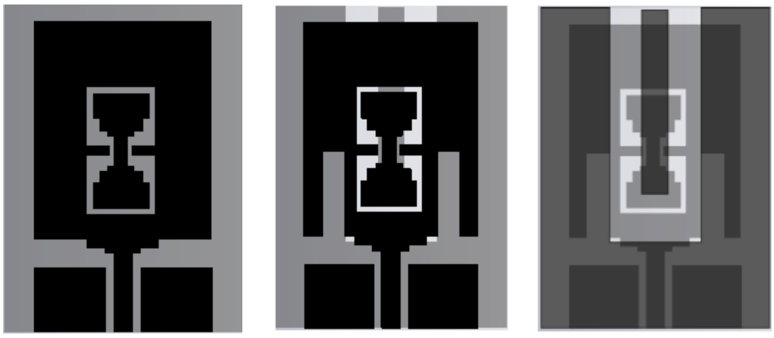


Figure 3. Prototype evolution of the proposed antenna structure

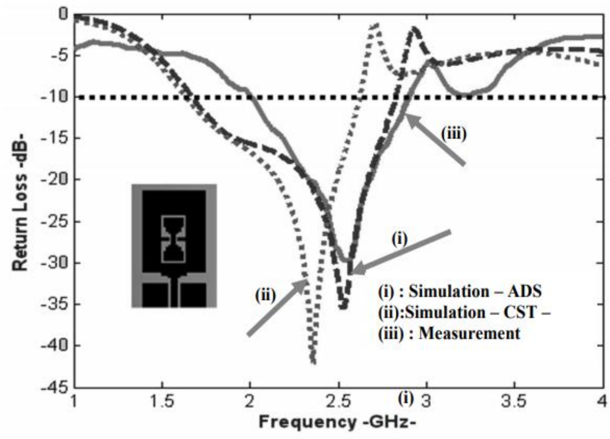
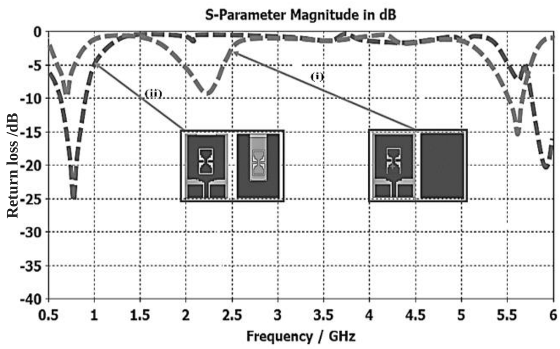
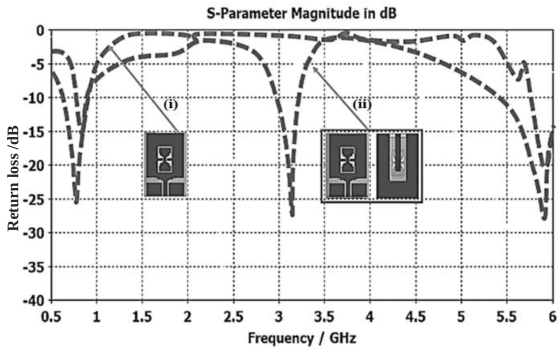


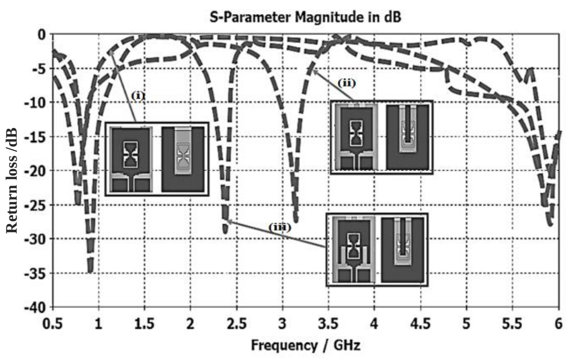
Figure 4. Return loss vs frequency simulation and measurement result of the antenna reference [23]



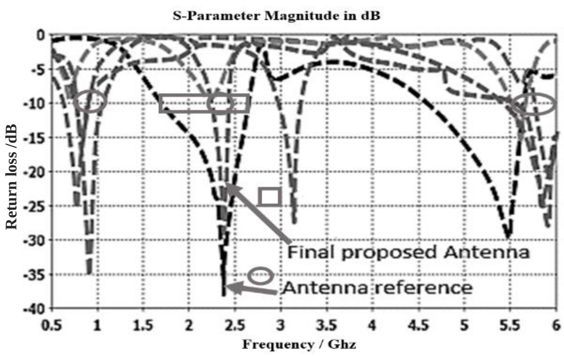
(a)



(b)



(c)



(d)

Figure 5. Return loss vs frequency of the proposed antenna for a different parametric study on CST (a) with a slot on ground plane, (b) with a stub tuning on ground plane, (c) with a symmetrical slots on radiator patch and (d) comparison S11 of the final proposed antenna structure with antenna reference

To validate the simulation results, we have used another simulation by using advanced design system from Agilent technologies [21]. The result obtain is present in Figure 6. The Table 2 show the comparison the geometry of the final validates monopole antenna structure with other RFID antenna published. This prototype has a small and miniaturized dimension.

The simulation gain of the proposed antenna for a different frequency resonance is plotted in Figure 7. We observed that the gain gradually increases with frequency-bands. The Figure 8 exhibits the simulated surface current distribution at 0.9 GHz, 2.4 GHz and 5.8 GHz. For a different frequency, it is noticed that surface current distribution is distributed along the radiator patch, slot shaped and a ground plane.

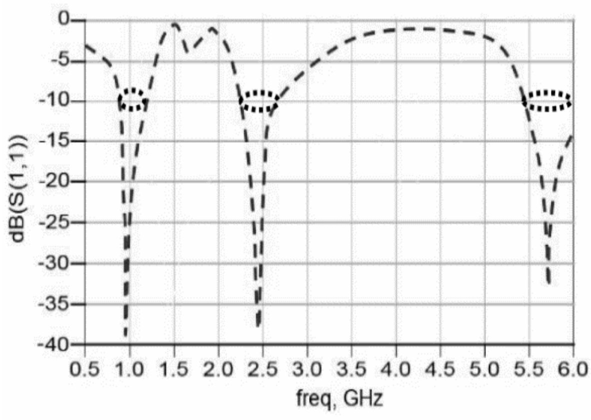


Figure 6. S11 vs frequency in ADS

Table 2. Comparison dimension of the proposed antenna with another compact antenna (published)

Published	Dimension (unit: mm)
Prototype developed	30x50
Prototype reference	114.7x79.6
[19]	65x65
[20]	150x150
[21]	139x139

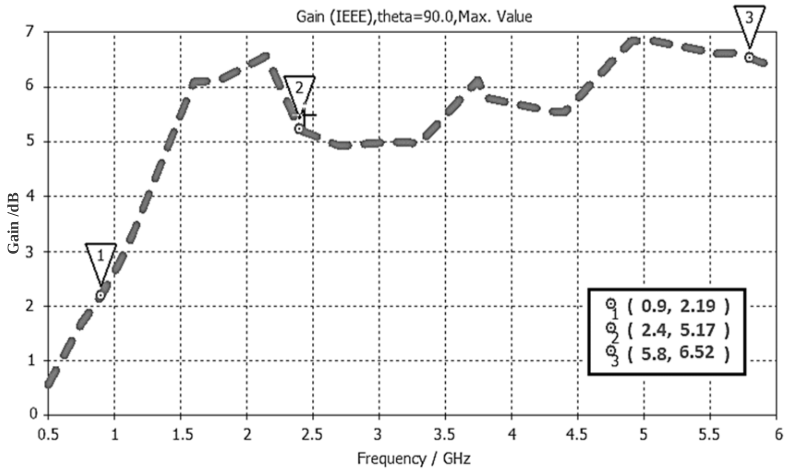
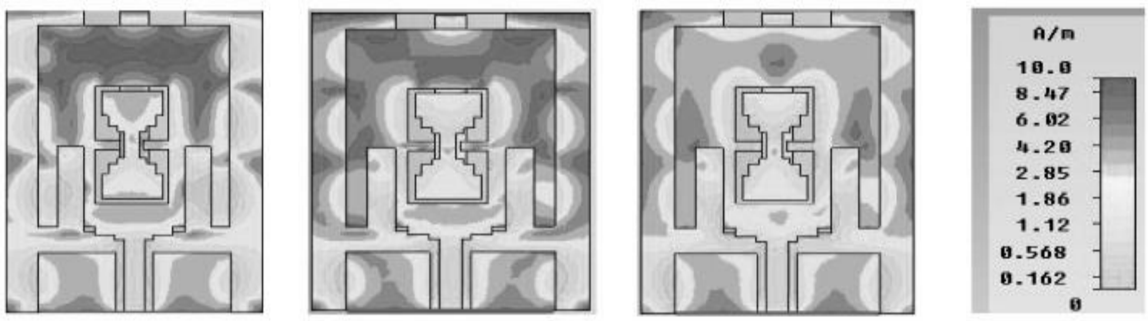


Figure 7. Gain vs frequency of the final propose planar antenna



(a) (b) (c)

Figure 8. Simulation current distribution at a different frequency (a) 0.9 GHz, (b) 2.4 GHz, and (c) 5.8 GHz

3. MEASUREMENT RESULTS AND DISCUSSION

After the study of the frequency resonance to adapt for a various RFID frequency band by using a two simulators' ADS and CST, the final prototype antenna structure has been achieved. The photograph of this fabricated antenna is shown in Figure 9. The measurement results compared with the simulation results of the m planar antenna achieved is presented in Figure 10. We observed a good agreement between the simulated and experimental results of the return loss. A slight difference is due to the different numerical methods used by a simulators ADS and CST. Which method of moment used by ADS and finite integrated techniques used by CST-MWS. Therefore, we conclude that we have a good agreement between simulation and measure results. This permit to validate a novel antenna structure for multiple frequency bands; 0.7 to 1.1 GHz, 2.2 to 2.5 GHz and 5.4 to 6 GHz covering 0.9/2.4 and 5.8 GHz RFID operation bands.

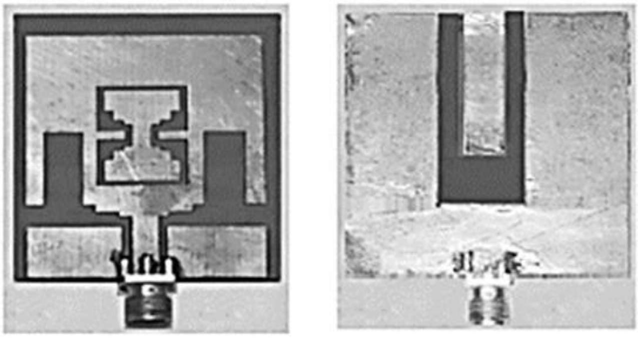


Figure 9. Proposed of antenna prototype

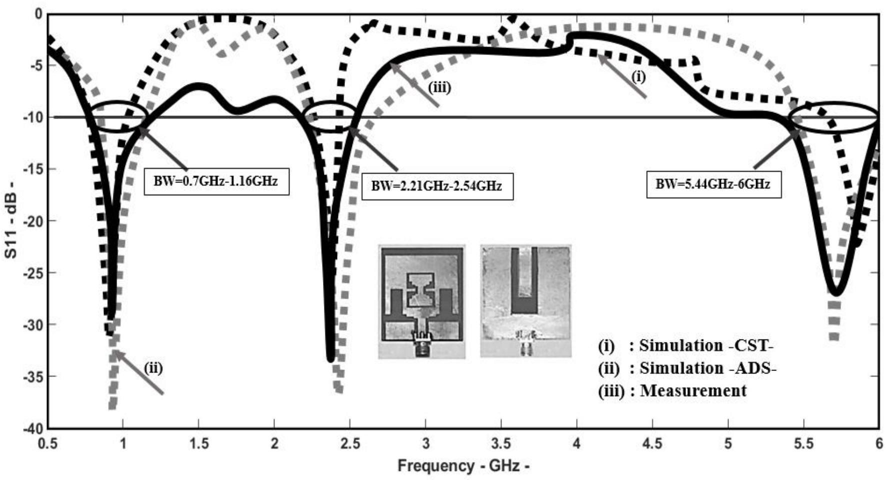


Figure 10. Comparison of simulated and measured return loss

Both the comparison measured matching input impedance and bandwidth of the fabricated prototype proposed is shown in the Table 3. The simulated 2D Far-field radiation patterns of the antenna on E-plane and H-plane at 0.9 GHz, 2.4 GHz and 5.8 GHz are presented in Figure 11. It is noted that the antenna shows a stable radiation over the different frequency resonances, which is a good omni-directional patterns in the E-plane and the almost bidirectional patterns.

Table 3. Comparison of antenna bandwidth with prototype reference

	Prototype reference	Proposed antenna
Size		50.8*30 mm^2
Bandwidth	2.1-2.8 GHz	0.7-01.1 GHz, 2.2-2.5 GHz and 5.4-6 GHz
Center Frequency	2.5 GHz	0.9 GHz, 2.35 GHz and 5.7 GHz
Impedance-bandwidth	28.57%	44.4%, 12.76% and 10.52%

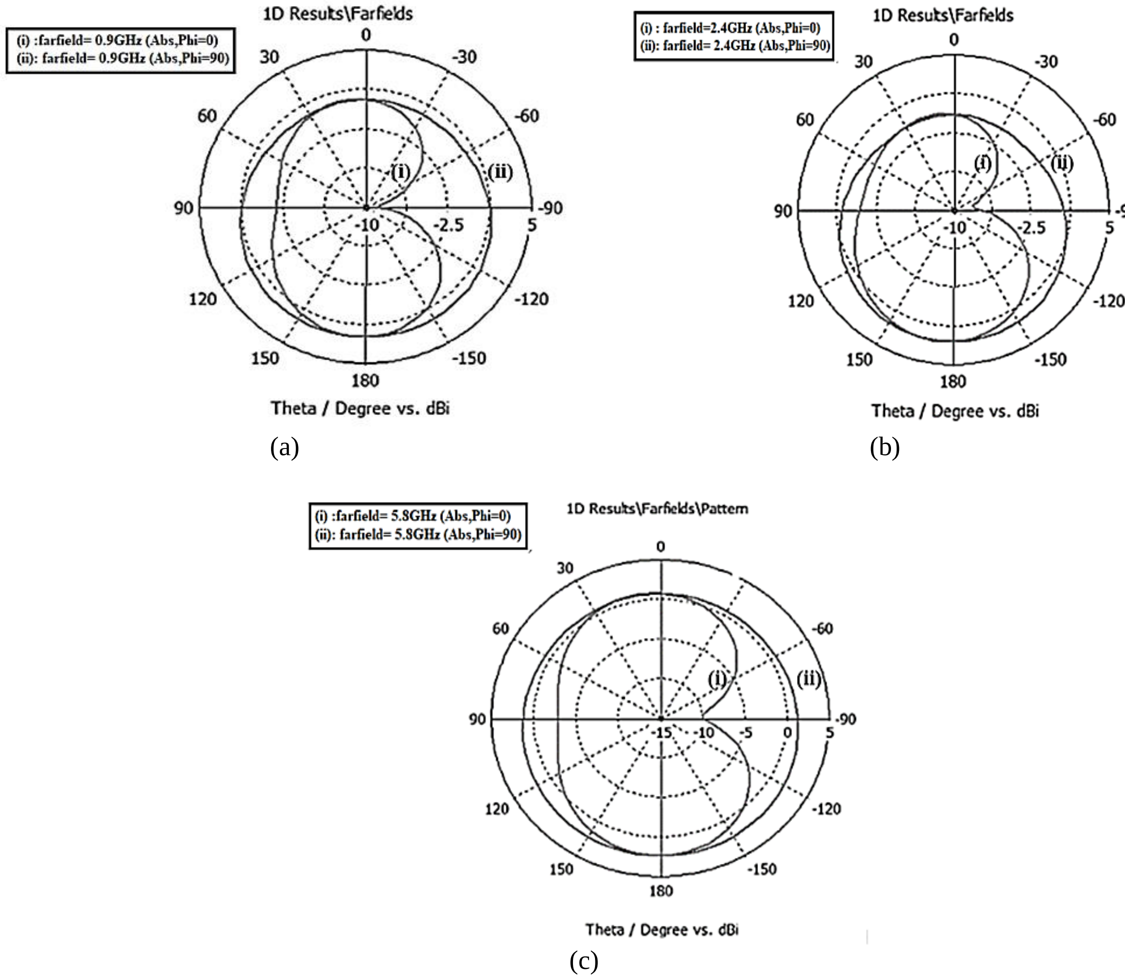


Figure 11. Simulation radiation patterns (a) 0.9 GHz, (b) 2.4 GHz, and (c) 5.8 GHz

4. CONCLUSION

In this research, we have designed and developed a new low-cost compact and miniaturized monopole multi-band antenna for a various RFID application such as ultra-high frequency band (0.9 GHz) and microwave frequency band (2.4-5.8 GHz) by using a grounded coplanar waveguide with U-slot, partial ground plane, stub tuning and a symmetrical slot with optimized dimensions. These parameters permit to validate a novel planar antenna for 0.7-0.9 GHz, 2.35-2.45 GHz and 5.65-6 GHz operating in various frequency band RFID applications.

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